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DOWNGRADED AT 3 YEAR INTERVALS; DECLASSIFIED AFTER 12 YEARS.
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REPORT NO. AC-62-0031

MISSILE OF INVESTIGATION REPORT-SUPPLEMENT NO. I (U)

Run S1-613-14-01

Run Date 13 May 1962

Issue Date 22 April 1963

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AUTHORIZED BY: AIR FORCE LETTER
SAN BERNARDINO AIR MATERIEL AREA (SBAMA)
DATED 17 NOVEMBER 1965

RECLASSIFIED BY: R J Cook
DEPT. 130-1 **DATE** 12-13-65

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SECTION 1

INTRODUCTION

Missile 1F and Sycamore Static Test Stand S-1 were destroyed by fire and a series of explosions that originated in the thrust section during Test, S1-613-14-01 on 13 May 1962. The scheduled engine firing durations were 40 seconds boosters, 60 seconds sustainer, and 65 seconds verniers. Actual durations were 1.77 seconds booster No. 1, 5.4 seconds booster No. 2, 1.23 seconds sustainer, and zero seconds for the vernier engines.

The incident was investigated by an Accident Investigation Board composed of members from the USAF, General Dynamics/Astronautics, Rocketdyne, Space Technology Laboratories, and Acoustica Associates. The cause and effects of the explosion were determined, and remedial action for subsequent missiles was established.

At the time of issuance of the Missile 1F Investigation Report (AC-62-0031) several investigative efforts initiated by General Dynamics/Astronautics and Rocketdyne were not completed. It is the purpose of this supplement to present the findings of these investigations.

The areas under investigation by General Dynamics/Astronautics were as follows:

1. The effects of sustainer engine gimballing and inertial loading on internal pump clearances with the GD/A lox pump inlet "Y" duct attached to the pump housing. This investigation was initiated by the failure of Missile 11F at launch on 9 April 1962 and was expanded following the Missile 1F explosion. The results of these investigations are summarized in Attachment 1.

2. The sustainer engine head suppression valve opening delay variations observed in data recorded at the various test facilities and the differences in the delay between Rocketdyne data and GD/A data. The results of these investigations are presented in Attachment 2.

3. Tests were initiated by GD/A to investigate the damage to the sustainer engine lox pump inlet Raco seal from Missile 11F. Missile 11F was unsuccessfully launched on 9 April 1962. The results of these tests are presented in Attachment 3 since the failures of Missiles 1F and 11F were similar in that a sustainer lox pump explosion occurred in each case.

Investigations conducted by Rocketdyne covered many areas. The published report of the results of their investigation is Investigation of Failure of Atlas Missile 1F During Static Test (Rocketdyne Report No. R-3705) dated 31 August 1962.

SECTION 2

SUMMARY

The chronological order of significant events follows using the booster engine start signal as zero time. Booster ignition start was normal. The sustainer ignition start signal was properly generated at 0.55 seconds, igniting the sustainer solid propellant charge and energizing a solenoid valve in the hydraulic manifold which applied opening pressure to the sustainer lox head suppression (HS) valve. The HS valve position indicator showed first opening movement at 0.67 seconds which was 120 milliseconds (MS) delay from the sustainer ignition start signal. The HS valve opened to an apparent 6 degree position by 0.70 seconds. Probably the valve didn't open at all - the 6 degrees could result from shaft torsion and slack in the valve linkage. The HS valve remained at the apparent 6 degrees position until 1.02 seconds (470 MS delay) when it started to move towards the open position. Rocketdyne found that delays over 430 MS will always cause the lox pump impeller to rub on the pump case wear ring or diverter lip. The sustainer lox pump had accelerated to its maximum spin charge speed by the time the HS valve started to open (after the 470 MS delay). The opening of the HS valve allowed lox to start flowing, and with the pump at this high speed, an excessive pressure imbalance in the lox pump volute resulted. The pressure imbalance on the lox impeller caused rubbing between the leading edge of the impeller and the diverter lip, at a point just upstream radially from the discharge leg (when viewed from the inlet duct of the lox pump). During this period the sustainer thrust chamber ignition sequence was continuing with hypergol ignition and propellant utilization (PU) valve movement.

The rubbing of the aluminum impeller and cadmium plated steel diverter lip caused self ignition of one or both of these pump parts (both were found burned). Initial indication of this burning was probably a surge in the sustainer lox pump inlet pressure starting at 1.29 seconds. The surge peaked at about 80 psig, dropped to 60 psig, then went off scale high (over 200 psig) at about 1.34 seconds when the sustainer lox pump was blown apart. The HS valve had opened to 45° by the time of the explosion (determined by examination of valve). Lox pump speed was 8,200 RPM.

The explosion and fire caused engine compartment temperatures to rise. By 1.75 seconds the engine compartment ambient temperature had increased to the redline value of 250°F. The high temperature automatically initiated engine cutoff at 1.77 seconds, shutting down the sustainer and booster No. 1 engines. The electrical control wires to the booster No. 2 engine were severed, and it continued to run until the first large thrust section explosion at 5.4 seconds. The fuel tank was apparently ruptured, and intermediate bulkhead failure probably occurred during this period. At 6.3 seconds the final large explosion completed the destruction of the missile, service tower, and considerable ground equipment. No personnel were injured.

Most of the missile hardware was recovered and examined. Investigations were subsequently conducted at Rocketdyne and General Dynamics/Astronautics (GD/A) and are reported in the attachments. GD/A found that even extreme interface

loads at the sustainer lox pump inlet flange could not deflect the pump housing enough to cause impeller rubbing (0.0031 inch inducer inlet housing deflection where the smallest impeller clearance on the 1F lox pump impeller was approximately 0.018 inch). (See Attachment 1)

GD/A tested the HS valves of several missiles to determine representative delay times from the sustainer engine ignition start signal to the first indicated movement of the HS valve. The HS valve on Missile 75F was tested first. The valve delay time was about 76 MS. Additional valve delay testing appeared desirable, and 2 weeks later an HS valve was again tested on Missile 75F, this time with more emphasis on obtaining accurate data. Also, the HS valve had been replaced by a valve with a desicant cap and improved sealing on the HS valve idler bearing assembly. Valve delay times averaged 51 MS, which was close to the 42-47 MS acceptance test times obtained at Rocketdyne (see Attachment 2). HS valve delay times were checked on Missiles 86F and 88F in the factory with results averaging 46 MS. HS valves on Missiles 67E and 57F, at OSTF-1 and OSTF-2, respectively, had average times of 43 MS. Data was collected from past firings at Sycamore Stand S1 (130-150 MS), Edwards Rocket Base Stand 1-4 (60-120 MS), and Atlantic Missile Range (AMR) (30-110 MS). The AMR data was recorded from commutated telemetry channels.

Rocketdyne conducted engine tests to determine the effect of various HS valve delays on lox pump shaft deflection (see Investigation of Failure of Atlas Missile 1F During Static Test, Rocketdyne Report R-3705). A lox pump was modified so minimum impeller clearance that occurred on each test could be measured. Liquid nitrogen was used in the lox pump and RP-1 in the fuel pump. The pumps were rotated by igniting the spin charge as in a normal engine start. Test results (corrected to lox temperatures) indicated no impeller rubbing up to 150 MS HS valve delay. Delays of 150 to 430 MS could cause rubbing depending on the amount of tolerance buildup during pump assembly. HS valve delays greater than 430 MS would always cause some lox impeller rubbing on the wear ring or diverter lip where minimum clearances occur (approx. 0.017 inch).

The HS valve on the last test of Missile 1F was found to have water and scaly rust deposits in the idler shaft needle bearing assembly. Rocketdyne conducted HS valve tests to determine if water and grit in an HS valve idler bearing cavity could effect HS valve opening. Liquid nitrogen was used to freeze the water. Test results indicated the opening of the HS valve would be delayed. On one test the HS valve did not open at all.

SECTION 3

CONCLUSIONS

Rocketdyne tests showed the delay in opening of the sustainer lox HS valve that occurred on the final test of Missile 1F could be simulated by contaminating the idler shaft bearing assembly with water and grit similar to that found in the Missile 1F HS valve idler bearing cavity. Also, tests verified that the HS valve delay time experienced on the last Missile 1F test would always cause rubbing of the lox impeller and wear ring or diverter lip. It was concluded that the impeller rubbing on Missile 1F started the fire and led to the explosion which destroyed the missile.

HS valves are being modified by Rocketdyne ECP MA3-316 which adds a desicant plug to the HS valve idler shaft bearing cavity. Also, ECP MA3-330 installs a non-combustible KEL-F liner in the lox pump inlet adapter and wear ring area to reduce the possibility of burning should rubbing occur.

To insure safe lox pump operation, Rocketdyne has recommended 75 MS as the maximum allowable sustainer lox HS valve delay time (time between ignition start signal and first valve movement). If a longer delay is observed, the valve operation should be investigated to determine the cause, possibly necessitating valve replacement.

ATTACHMENT 1

SUSTAINER LOX PUMP/INLET DUCTING INTERFACE

GENERAL DYNAMICS/ASTRONAUTICS

376-4-022
27 November 1962

TO: A. B. Cox, Dept. 360-2

FROM: H. A. Hunter, Dept. 376-4

SUBJECT: Sustainer LO_2 Pump/Inlet Ducting Interface.

REFERENCE: GD/A Action Item No. 5 - STL Memo 6101-7855-TC-006, dated 12 Oct. '62.

The purpose of this memo is to report the results of the two series of tests which were conducted on the tail section test stand concerned with interface loads and deflections at the sustainer engine turbo pump.

The first series of tests were performed with the intent of measuring the relative deflection between the impeller shaft and the inducer inlet housing as a function of various applied load variables. The applied load variables consisted of line pressures, inertias, temperature, manufacturing tolerances and engine gimbal angles. These gap changes were determined by means of a Rocketdyne furnished "spider transducer" which was inserted into the inducer housing to measure the relative movement at three points around the circumference of the housing. The attached LO_2 sustainer line was subjected to extreme adverse positions along with maximum external applied load in order to obtain an ultimate gap change in the area of investigation (Ref. Fig. 1). The detailed test procedure is presented in Memo ASA-62-052, while the results are shown in Report 27B-1599-1. The test results indicate a maximum change in relative deflection of .0031 inches. This deflection had been recorded while the following applied load sources and sustainer line conditions were present.

1. Fuel Duct pressurized to 60 psig.
2. LO_2 Duct pressurized to 62 psig.
3. Misalignment of .50" in the +"x", +"y" and +"z" directions. (Max.).
4. 3 G inertia load in the +"x" direction. (Max.)
5. 8 G inertia load in the +"z" direction. (Max.)
6. The gimbal block was adjusted .415" in the -"x" direction and .27" in the -"y" direction. (Max.)
7. 3° gimbal angle in both pitch and yaw directions. (Max.)

The resulting deflection of the inducer inlet housing (.0031") is considered very small without considering that the applied simultaneous loadings impose an extreme loading condition which is hardly realistic.

It was further anticipated that the actual interface loads could be measured in this area by means of an instrumented inducer inlet adaptor, therefore, a second series of tests was initiated to accomplish this task. Strain gages were fitted to the adaptor in order to develop a load cell transducer that would measure (6) interface loads to the sustainer engine turbo pump. The test procedure for this phase of testing is presented in Memo ASA-60-056. As in the first series of tests, the LO_2 sustainer line was subjected to all possible adverse positions along with simultaneous maximum external loading. The loading variables were applied separately and in increments with an attempt to measure input from each external load contribution. This proved very unsuccessful, since the system displayed non-repeatability, and non-linearity. Hysteresis which was present in the mechanical system or sensitivity in the transducer circuits were such that it resulted in non-interpolative data. For this reason it is impossible to arrive at a specific set of compatible interface loads which would represent a particular missile flight condition as is presented in Report AE60-0811 (Booster and Sustainer Engine Interface Data).

Below is a list of the maximum interface loads recorded during various phases of the testing. These loads include the combined effects of the variable external inputs, such as manufacturing tolerances, inertia effects, engine gimbal, temperature, pressure and maximum adjustments in the gimbal block, which constitute the same criteria as when the deflection of .0031 inches was recorded. The NAA (Rocketdyne) furnished allowable interface loads are also shown for reference.

	Maximum Loads Recorded During Test	Maximum Loads From Report AE60-0811	(NAA) Rocketdyne Furnished Allowable Loads
F_x	1171 lbs	1168 lbs	200 lbs
F_y	432 lbs	593 lbs	200 lbs
F_z	701 lbs	1017 lbs	1000 lbs
M_x	2607 in. lbs	4798 in. lbs	3000 in. lbs
M_y	5115 in. lbs	4857 in. lbs	3000 in. lbs
M_z	4056 in. lbs	5086 in. lbs	3000 in. lbs

The NAA allowable interface loads are indicative of a simultaneous condition whereas the recorded interface loads are maximum values which occurred during different phases of the test. A complete record of the test results are shown in Reports 27E-1605-1 and 27B-1623-1. The table above also presents the maximum interface loads as given in Report AE60-0811 so that a comparison analysis can be made between the two sets of loads data. May it be pointed out that the test results indicate values of approximately the same magnitude as

presented in Report AE60-0811, therefore, the loads shown in the previously released report will be used for specific flight conditions. It is impossible to refine these values any further than already has been accomplished in Report AE60-0811, using the data obtained with the instrumented inducer inlet adaptor.

Recommendations: Further investigation of subject area (Ref. Fig. 1) be dropped since we are of the opinion that the system accomplishes its intended task satisfactorily without jeopardizing NAA hardware.

/s/ H. A. Hunter
Stress Group Eng. (AWS)

/s/ C. O. Ekrem
Chief of Stress (AWS)

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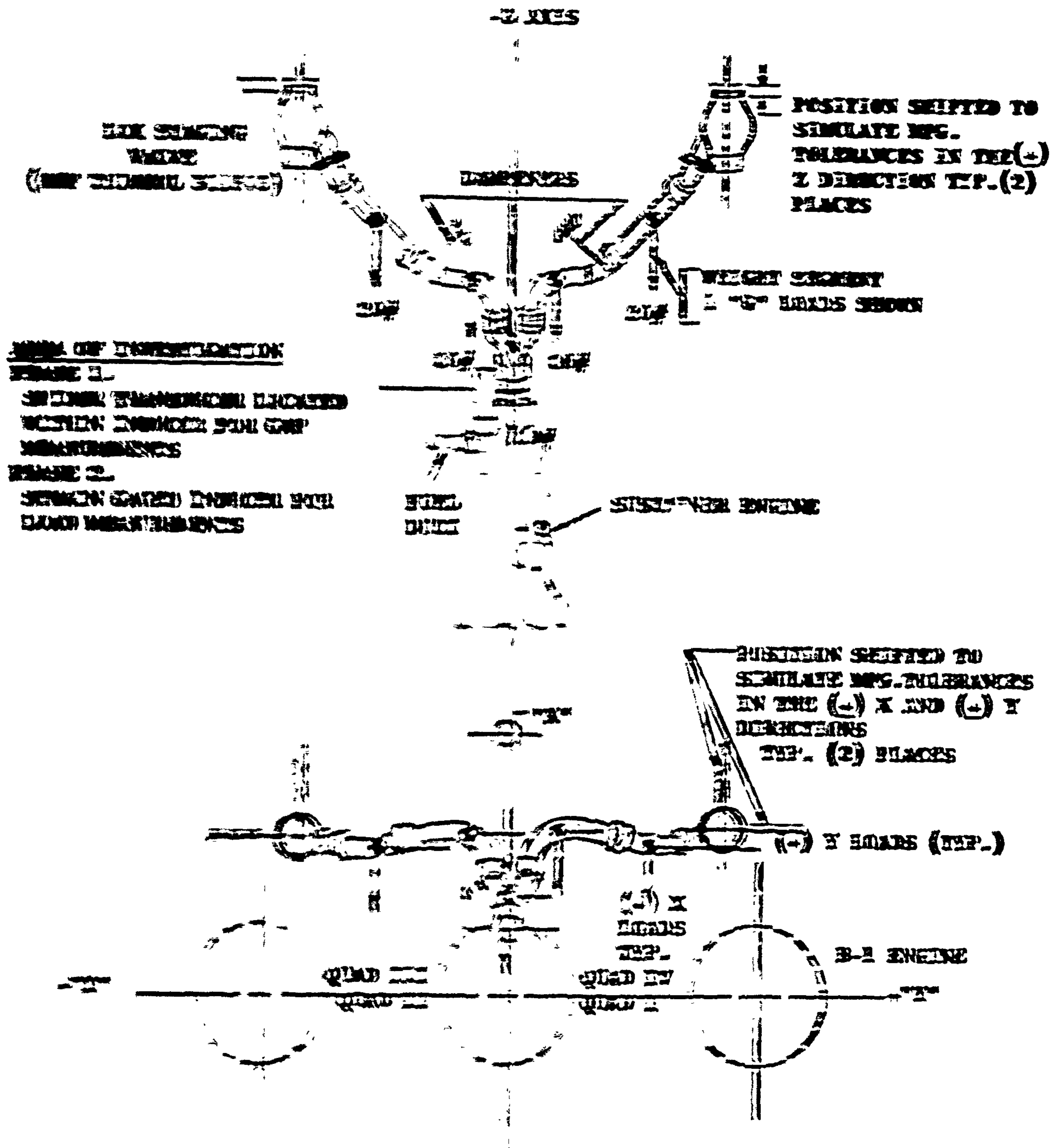
ATTACHMENT 1

FIGURE 1

TEST SET UP FOR LOAD AND GAP MEASUREMENTS



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ATTACHMENT 2

SUMMARY OF HEAD SUPPRESSION VALVE OPENING TESTS

EM-2165
24 July 1962

To: Distribution

From: Test Evaluation

Subject: Summary of Special Head Suppression Valve Tests - Missiles 75F, 86F, 88F, 67E, and 57F.

Investigations initiated following the destruction of Missile 1F during Test S1-813-14-01 on 13 May 1962 revealed an anomaly concerning opening of the sustainer engine head suppression (HS) valve on GD/A conducted tests. The anomaly involved the time interval between sustainer engine ignition signal and first indicated movement of the HS valve. Rocketdyne engine acceptance test data indicated 42 to 47 milliseconds (MS) for this time interval. MA-3 engine firings conducted by GD/A indicated three general groups of ΔT's as follows:

		ΔT
(a)	Sycamore Test Stand S1	120 - 150 MS
(b)	Sycamore Test Stand S2 and ERS Test Stand 1-4 ("F" Engine)	50 - 80 MS
(c)	AMR Flights	30 - 110 MS

The AMR flight data is believed to be the least reliable due to the fact that HS valve position data is recorded on commutated telemetry channels.

Exploratory testing was initiated on 75F at Sycamore continued on 86F and 88F in the factory and on 67E at OSTF 1 and 57F at OSTF 2 in an attempt to define differences between Rocketdyne and GD/A data and to determine the reasons for any difference.

Conclusions

1. HS valve first movement delay is comparable to that on Rocketdyne acceptance runs for 75F, 86F, 88F, 67E and 57F.

2. The second set of HS valve tests conducted on 75F have established that the FM recording system does not introduce a time lag in valve response data.

3. The reason for the previous S-2 and original 75F ΔT anomalies has not been determined.

Test S2-6BP-01-75 (1 June)

Investigations were begun utilizing Missile 75F at Sycamore Test Stand S-2. Four tests were conducted on this missile, two at 2,000 psig ground hydraulic pressure and two at 3,000 psig ground hydraulic pressure (the pressure level used in Rocketdyne testing). Instrumentation was provided to measure the normal sustainer ignition start signal (P1545X), voltage at the solenoid in the hydraulic manifold (P1124V), SPGG ignition signal (P1099V), opening (H1408P) and closing (H1435P) hydraulic pressure to the HS valve, and the HS valve position (P1529D). Also measured were various additional hydraulic system pressures and propellant utilization (PU) valve parameters. Each of the four tests consisted of the application of a start signal to the system, opening of the HS and PU valves, opening of the gas generator blade valve, placing of the HS and PU valves on control, removal of the start signal and closing of the valves.

Data from these tests (presented in Table I) indicated that the ΔT from start signal to HS valve first movement was 80 MS and 72 MS at 2,000 psig hydraulics and 70 MS and 70 MS at 3,000 psig hydraulics. HS valve opening and closing pressure data indicated that the HS valve should have begun moving approximately 32 MS prior to the first recorded movement. This was established by comparing the recorded data with data provided by Rocketdyne. The Rocketdyne data showed that first movement of the HS valve corresponded with the initial peak in opening pressure applied to the valve and simultaneously with the low point in closing pressure at the valve.

It should be noted at this point that the Missile 75F ΔT data was not inconsistent with the previous test Stand S-2 data obtained during the testing of Missiles 2E, 6E, 5E, 62E, 33F and 59F, at that facility. However, since the HS valve opening and closing pressures (measured for the first time by GD/A at a captive site), when compared with the Rocketdyne furnished data, indicated a 32 MS delay in HS valve response, it was suspected that the FM recording system was responsible for the delay in some unknown manner.

To determine if this was the case the following check was made: A signal was simultaneously inserted into two circuits in the S-2 transfer room. One circuit was fed directly to an oscillograph in the blockhouse and the other circuit was routed through the FM system and recorded on the same oscillograph as the first circuit. The difference in time of the receipt of the signal by way of the two circuits was less than 3 MS.

An additional anomaly was observed in the data recorded during these tests. The FM system recording of the start signal (P1545X) was observed to consistently lag the Easterline Angus pen (EA) recording of the same signal. The values were 9, 6, 12, and 10 MS for the four tests. The reason for this

anomaly has not been determined as yet; however, even if this lag were applied to the HS valve first movement data the data still does not compare with the Rocketdyne results.

Factory Tests (15 & 18 June)

Since the test schedule of 75F in support of "Operation Shotgun" precluded the availability of the missile for immediate additional testing and since it was considered desirable to obtain data concerning the ΔT from an additional source, factory tests were scheduled utilizing Missiles 86F and 88F on the line. The tests consisted of the application of a 28V DC source to the solenoid in the hydraulic manifold with 2,000 psig and 3,000 psig ground hydraulic pressure in the system, as indicated in Table II. Instrumentation was provided to record the 28V signal (P1124V) application and the HS valve position (P1529D) only. The data were recorded on an oscillographic recorder (CEC). Data from these tests compared closely with the Rocketdyne acceptance test figures.

Additional 75F Tests (21 June)

Since schedule slippage provided the opportunity for additional tests on 75F and since the results of the factory tests indicated the desirability of additional tests on this missile, a test format similar to that of 1 June was established. In the time interval between 1 and 21 June the HS valve on this missile had been replaced by one incorporating the desicant cap on the idler shaft and double shaft seals.

Instrumentation was provided at Stand S-2 to record the normal ignition start signal (P1545X), voltage at the solenoid in the hydraulic manifold (P1124V), closing pressure to the HS valve (H1435P), and the HS valve position (P1529D).

Since the FM recording system was still suspect as a contributing factor to the anomalous ΔT, provision was made to record the data on a CEC recorder located at the test stand for the first series of tests. For the next series of tests the CEC recorder was located in the blockhouse, and on the last series of tests data was recorded by way of the FM system. Each series of tests consisted of several valve actuations at both 2,000 psig and 3,000 psig ground hydraulic system pressure.

The results of these tests indicated that the FM system did not contribute a time lag to the recorded data. All ΔT's agreed closely with the Rocketdyne acceptance test data and the 86F and 88F data.

The venting of HS valve closing pressure to return was followed within 1 to 2 MS by first valve movement on the CEC records and within 8 to 13 MS on the FM recorded data. Table III presents the results of each series of tests.

Since the HS valve had been replaced between the series of tests on this missile, a check was made to determine if the ΔT data differences were due to an HS valve position potentiometer anomaly. The resistance of the potentiometer on the original HS valve was measured and was found to be within

specifications.

Data accumulated on this second set of 75F tests again indicated that the EA recording of the ignition signal led the FM recording of it by from 1 to 11 MS. In addition, it was observed that the EA recording of the signal also led the CEC recording except for two instances. In one of the 19 valve actuations recorded by CEC the EA recording of the start signal lagged the CEC recording by 1 MS and in one instance occurred simultaneously with it. In the remaining 17 tests the EA recording led the CEC recording by from 5 to 14 MS.

Additional Data

Rocketdyne investigations since the destruction of Missile 1F on Test S1-613-14-01 have established that an HS valve opening delay in excess of 75 MS could lead to rubbing of the stationary and rotating internal parts of the lox pump. To insure that the ΔT between firing signal and first HS valve movement was less than this value, tests were conducted on Missiles 67E (on 26 June) and 57F (on 28 June), the next missiles scheduled for launch at OSTF 1 and 2, respectively.

The tests were conducted using 2,000 psig hydraulic pressure and provision was made to record the HS valve position and firing signal only. The data were recorded simultaneously on a CEC recorder and the FM system. The results of these tests compared very well with the Rocketdyne acceptance test data. There were no significant differences noted between the ΔT's as indicated by each recording system. The 67E and 57F test results are tabulated in Table IV. Checks of this nature are also planned on the following missiles prior to their respective launch: 64E, 7F, 8F, 10F, 13F, 14F, 16F, 21F and 87F. In the event that any of these tests indicate a ΔT in excess of 75 MS, provision has been made to conduct tests to determine the cause.

A hot firing test of Missile 75F was conducted on 3 July, Test S2-601-A2-75. The scheduled firing durations were not achieved; however, approximately 35 seconds of mainstage engine operation was obtained. HS valve data recorded on this firing test indicated a ΔT between start signal and first valve motion of 54 MS via CEC recording and 60 MS via FM recording. These times compare favorably with the 21 June test results on 75F (no lox aboard missile) in which HS valve first movement average times of 49 MS and 52 MS were recorded on the blockhouse CEC and FM system respectively.

Voltage at the control solenoid (P1126V) during this test was measured at 29.2 V DC and on the ignition start signal measurement (P1099V) as 29.6 VDC. There were no voltage oscillations or dropouts indicated by these measurements during the firing.

Prepared by /s/ D. W. Healy

Approved by /s/ H. P. Eldridge

ATTACHMENT 2
EM-2165

TABLE I

MISSILE 75F TESTS CONDUCTED 6/1/62

Test No.	P1545X Sust. St. Sig. EA	P1545X Sust. St. Sig. FM	HS Vlv. First Movement	HS Vlv. Full Open	△ T P1545X EA To HSV 1st Move.	△ T HSV Closed To Full Open	HS Vlv. Open Press. St. Rise	HS Vlv. Clos. Press. St. Drop
1	0	.009	.080	.685	.080	.605	.045	.046
2	0	.006	.072	.677	.072	.605	.040	.044
3	0	.012	.070	.565	.070	.495	.040	.044
4	0	.010	.070	.566	.070	.496	.040	.043

Test No.	PU Vlv. First Mvmt.	PU Vlv. Full Open	△ T PU Closed To Open	PU Open Press. St. Rise	P1124V Volt. @ Starts Rise	Man. Sol. Reaches 28 Volts	P1099V Starts Rise	SPGG Fire* Reaches 28 Volts
1	.330	.930	.600	.307	.011	.015	.015	.040
2	.330	.917	.587	.297	.006	.011	.010	.035
3	.321	.820	.499	.298	.012	.016	.016	.040
4	.330	.813	.483	.295	.010	.014	.014	.039

Note: Tests 1 and 2 were conducted with 2,000 psig ground hydraulics, Tests 3 and 4 with 3,000 psig. All times are referenced to the EA occurrence of P1545X the sustainer engine ignition stage control signal.

Voltage measured by P1124V was 28.7 VDC average for the four tests.

* The recorded time lag between P1124V and P1099V is accounted for by the difference in frequency response between FM Channels 5 and 12.

ATTACHMENT 2
EM-2165

TABLE II

FACTORY HEAD SUPPRESSION VALVE TEST RESULTS

Msl. No. 86F Test Date 6/15/62			Msl. No. 86F Test Date 6/18/62			Msl. No. 88F Test Date 6/18/62		
Test No.	ΔT (MS)	Hyd. Press. (psig)	Test No.	ΔT (MS)	Hyd. Press. (psig)	Test No.	ΔT (MS)	Hyd. Press. (psig)
1	47	2000	9	46	2000	1	44	2000
2	54	2000	10	Data lost	2000	2	42	2000
3	50	2000	11	54	2000	3	44	2000
4	43	2000	12	51	2000	4	46	2000
5	46	3000	13	42	3000	5	36	3000
6	45	3000	14	50	3000	6	37	3000
7	45	3000	15	53	3000	7	37	3000
8	40	3000	16	48	3000	8	37	3000
			17	44	2000	9	33	3000
			18	43	2000	10	39	3000
			19	43	2000			
			20	42	2000			
			21	40	3000			
			22	39	3000			
			23	40	3000			
			24	44	3000			

T = time from voltage at hydraulic manifold solenoid to first movement of HS valve position trace.

Average ΔT at 2000 psig Missile 86F-47 MS (11 tests)
Average ΔT at 2000 psig Missile 88F-44 MS (4 tests)
Average ΔT at 2000 psig Missiles 86F and 88F-46.2 MS (15 tests)

Average ΔT at 3000 psig Missile 86F-44.3 MS (12 tests)
Average ΔT at 3000 psig Missile 88F-36.5 MS (6 tests)
Average ΔT at 3000 psig Missiles 86F and 88F-41.7 MS (18 tests)

Note: Voltage at the hydraulic manifold solenoid was not quantitatively measured for these factory tests.

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ATTACHMENT 2
EM-2165

TABLE III

MISSILE 75F TESTS CONDUCTED 6/21/62

CEC Recorder at Test Stand

Test	Hyd. Press.	ΔT(MS)
1	2000 psig	52
2	2000 psig	48
3	2000 psig	52
4	2000 psig	49
5	3000 psig	48
6	3000 psig	48
7	3000 psig	48
8	3000 psig	46

CEC Recorder at Blockhouse

Test	Hyd. Press.	ΔT(MS)
1	2000 psig	52
2	2000 psig	48
3	3000 psig	51
4	2000 psig	49
5	2000 psig	47
6	2000 psig	48
7	2000 psig	50
8	2000 psig	48
9	3000 psig	Data Lost
10	3000 psig	46
11	3000 psig	46
12	3000 psig	49

FM System Data

Test	Hyd Press.	ΔT(MS)
1	2000 psig	56
2	2000 psig	51
3	2000 psig	49
4	2000 psig	53
5	3000 psig	45
6	3000 psig	48
7	3000 psig	48
8	3000 psig	48
9	3000 psig	48

Note: Voltage at the hydraulic manifold solenoid averaged 26.1 volts for these tests.

ATTACHMENT 2
EM-2165

TABLE IV

Missile 67E at OSTF 1 on 6/26/62

CEC Data		FM Data	
Test	ΔT MS	Test	ΔT MS
1	Not recorded	1	50
2	48	2	45
3	44	3	49
4	39	4	49
5	46	5	43
6	42	6	41

Missile 57F at OSTF 2 on 6/28/62

CEC Data		FM Data	
Test	ΔT MS	Test	ΔT MS
1	42	1	Not Recorded
2	40	2	45
3	41	3	41
4	40	4	42
5	43	5	43

Note: 1. On these OSTF tests the data was recorded simultaneously on each of the recording systems.

2. Voltage at the hydraulic manifold solenoid on 67E averaged 28.2 VDC and on 57F averaged 29.2 VDC during the tests.

3. All tests run at 2000 psig hydraulic pressure.

ATTACHMENT 3

SUSTAINER LOX PUMP INLET RACO SEAL EXPLOSION TESTS - POINT LOMA

TO: Distribution

FROM: Propulsion Design

1. Project Office request dated 23 April 1962 requested a program to investigate the cause of the RACO seal failure in Missile 11F.

2. Test Lab request dated 8 May 1962 to perform seal explosion test on simulated duct filled with lox.

3. Three tests were performed at GD/A Point Loma on 9 June, 20 June and 26 June 1962. Results are summarized in Test Lab Report 27B 1594-1 dated 16 October 1962. Data is tabulated in Test Lab Report 27-1601-1.

A. Test Conditions

Simulated sustainer low pressure lox duct approximately 5 ft long with one bellows section and a sustainer lox pump inlet Raco seal at the explosive end. Varying amounts of Pentaerythritol Tetranitrate (PETN) sheet explosive were placed in the Raco seal end of the duct which was closed. The duct assembly was filled with lox. These conditions simulated the 11F sustainer lox system with the lox pump originating the explosion. The top of the duct was open and used for observation to assure being full of lox.

B. Hardware Test Results

Of three explosions detonated the one with 8 square inches x ¼" thick of PETN most nearly simulated the 11F hardware damage and data traces. The duct bellows section was destroyed and the Raco seal was blown out of the seal groove. The teflon part of the seal was torn into many pieces. The steel backup ring had an approximate 1 inch piece missing.

C. Test Data Analysis

Four pressure transducers were installed for the test. One was a direct mounted Statham 0-2000 psig with a .05 inch orifice. This orifice was installed after the transducer was ruined on the first test when the pressure rose past 2000 psig in one millisecond. The other three transducers were Bourns flight type 0-1000 psia with tubes and checkout shuttle valves simulating flight configuration for measurements P337P, P351P and P967P.

The direct mounted transducer peaked 1070 psig at 3 milliseconds after explosion start and to a maximum peak of 1165 psig at 8 milliseconds.

The P351P transducer peaked to 370 psig at 9 milliseconds after explosion start and the P967P transducer peaked to 545 psig at 6 milliseconds. The P337P transducer failed. The pressure decays to 20% of their peak value occurred by an average 18 milliseconds after explosion zero.

This data is not comparable with 11F flight data as the time between commutated data segments is 15-20 milliseconds. Typical 11F rise time between explosion zero and peak pressure is 18 milliseconds and decay time between peak pressure and 20% of peak pressure is 28 milliseconds.

4. **Conclusion**

This test showed that with a simulated sustainer lox pump explosion, the pump inlet Raco seal and duct bellows would fail in a manner similar to 11F. The test data is similar in appearance to 11F data with approximately twice as fast response. The damage to the duct bellows and Raco seal back-up ring were very similar to 11F. The Raco seal teflon insert incurred only slight damage on 11F, while in this test it was blown out of the duct.

Prepared by: J. Prescott